Learning Curves for Cost Estimation

Source: http://mgtclass.mgt.unm.edu/Togo/MGT%20503%20In-Class/Curvilinear%20Handout.DOC

Introduction

Learning curves are used by managers to formulate low-cost production strategies in increasing market share, or to address decisions such as make or buy a product, add or drop a product line, cost-volume-profit decisions, and setting product prices. Yet, management instructors seldom expose students to learning curves. When learning is taught in the classroom, no historical data is analyzed and learning is estimated using assumptions as to a model and its learning rate. Furthermore, when an analysis of learning is performed, it is preceded with a logarithmic transformation of the learning power function into a linear relationship; hence, the students are left with the misconception that all costs are inherently linear. This brief exercise uses the enhanced capabilities of spreadsheets to a) perform curvilinear data analysis, b) derive a learning model, and c) predict direct labor hours for cost estimation.

Learning Curve Overview

The learning curve relationship is commonly modeled with a power function described as the log-linear or constant percentage model. The log-linear model below recognizes that labor hours decrease systematically by a constant percentage each time the volume of production increases geometrically (usually a doubling of units).

$$(A, \text{ or } I_n) = aX^b$$

The choice of a dependent variable depends on whether the cumulative average-time learning model (A) or the individual unit-time learning model (I_n) is selected. Hence, the left side of the relationship is either: A = the average cumulative labor hours for X number of units, or I_n = the number of labor hours required to produce the last nth unit. The independent variables are defined as: a = the number of labor hours required to produce the first unit, X = cumulative number of units produced, and b = learning exponent, which is always negative. The negative learning exponent b is (log **r**)/(log **f**), where **r** is the rate of learning represented by the constant percentage decrease in hours, and **f** is the factor increase in output (usually in terms of 2). For example, an 80% learning rate with a doubling of units has a learning exponent b equal to –0.3219, which is (log .80)/(log 2).

Learning Curve Exercise

The objective of this exercise is to prepare a bid for the building of 15 XYZ smart missiles. Your company built the XYZ prototype because of its experience building an earlier version. When the XYZ missile manufacturing specifications were released, the government also released details of the $1,600,000 cost in building the prototype. In addition to direct materials, direct labor, and variable manufacturing overhead, other manufacturing overhead costs were 10% of total variable manufacturing costs. The $170,000 equipment purchased by the government will be made available to the selected contractor.

Direct materials	$ 800,000
Direct labor (4,000 hours @ $100)	400,000
Variable manufacturing overhead (4,000 hours @ $25)	100,000

Other manufacturing overhead ($1,300,000 @ 10%)	130,000
Purchase of reusable equipment	170,000
Total	$ 1,600,000

With your highly skilled labor force, the 4,000 direct labor hours incurred for the prototype should not be assumed for each of the fifteen XYZ missiles because of anticipated learning effects. Assume that the next fifteen XYZ missiles can be built with the same amount of learning that occurred in the production of the sixteen ABC missiles, the earlier version of the XYZ. The direct labor hours for each of the sixteen ABC missiles are listed below:

1.	3,900	2.	2,740	3.	2,660	4.	1,980
5.	2,320	6.	2,000	7.	1,900	8.	1,700
9.	1,950	10.	1,950	11.	1,760	12.	1,540
13.	1,680	14.	1,320	15.	1,500	16.	1,100

Curvilinear Data Analysis

There are two related analyses: what learning curve model to adopt, and its percentage of learning. Generate a scatterplot of the direct labor hours incurred for the sixteen ABC missiles, and add to it a power function curve, equation, and r-squared value. This is performed for a) the individual unit-time and b) the cumulative average-time models. Then determine which model is best, and calculate the learning rate to be used with the best model.

Using the spreadsheet EXCEL, enter the data for the ABC missiles into two columns labeled as Unit and Individual, and then add columns for Total and Average. For the individual unit-time method, highlight the two columns Unit and Individual. Using Chart Wizard, select XY (Scatter) as the chart type to generate the plot. With a right click on a data point within the graph, select Add Trendline and then Power as the trend type from the drop down menus. Staying within Add Trendline, select the Options tab and check Display equation on chart and Display R-squared value on chart.

Exhibit 1 displays the result for the individual unit-time model. The estimated learning curve is $Y = 3{,}798\ X^{-0.3582}$ and its r-squared value is 0.8722. For the cumulative average-time model, repeat the above steps except substitute Individual with Average. The estimated learning curve is $Y = 3{,}944\ X^{-0.2367}$ and its r-squared value is 0.9968.

The data analysis supports the use of the cumulative average-time model because of its larger r-squared value (.9968 versus .8722). The EXCEL formula for computing the learning rate for the cumulative average-time model is 10^(-0.2367*Log(2)) or rounded to 85%.

Cost Estimation With Learning

Estimate the cost for the next 15 XYZ missiles using the cumulative average-time model and the learning rate of 85%. Use the EXCEL formula ROUND(4000*16^(Log(0.85)/Log(2)),0) to compute the 2,088 average direct labor hours to complete the 16 XYZ units, given 4,000 hours for the prototype. The total number of hours estimated to complete 16 units is 33,408 (2,088*16), therefore, the number of hours to complete the 15 XYZ missiles beyond the prototype is 29,408 (33,408-4,000).

An estimate of $17,243,600 is calculated for the next fifteen XYZ missiles.

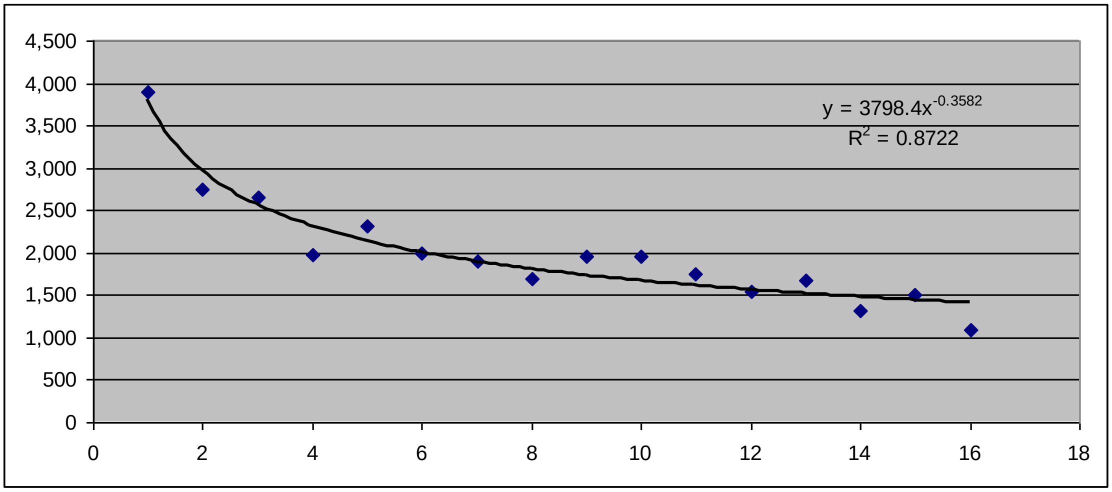
Direct materials ($800,000*15)	$ 12,000,000
Direct labor (29,408 hours @ $100)	2,940,800
Variable manufacturing overhead (29,408 hours @ $25)	735,200
Other manufacturing overhead ($15,676,000 @ 10%)	1,567,600

Total	$ 17,243,600

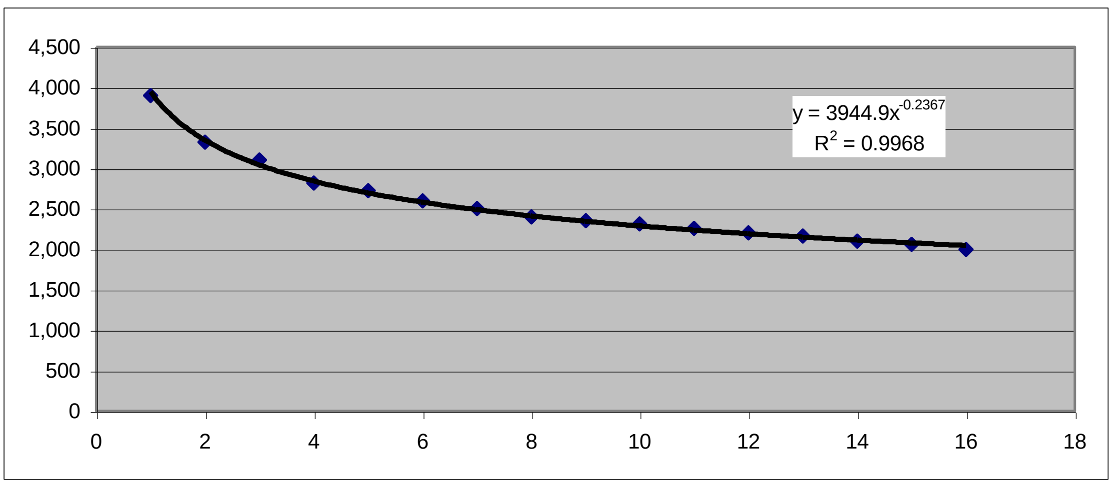
Exhibit 1: Learning Curve Data and Models

Unit	Individual	Total	Average	Unit	Individual	Total	Average
1	3,900	3,900	3,900	9	1,950	21,150	2,350
2	2,740	6,640	3,320	10	1,950	23,100	2,310
3	2,660	9,300	3,100	11	1,760	24,860	2,260
4	1,980	11,280	2,820	12	1,540	26,400	2,200
5	2,320	13,600	2,720	13	1,680	28,080	2,160
6	2,000	15,600	2,600	14	1,320	29,400	2,100
7	1,900	17,500	2,500	15	1,500	30,900	2,060
8	1,700	19,200	2,400	16	1,100	32,000	2,000

Individual Unit-Time Model



Cumulative Average-Time Model



Requirements:

1. Prepare a bid for 15 UVW rocket launchers given the following data for the prototype. The bid should identify which model, cumulative-average or individual unit, is being used to estimate direct labor hours, and its learning rate (rounded to the nearest percent).

Direct materials	$600,000
Direct labor (2,000 hours @ $100)	$200,000
Variable manufacturing overhead (2,000 hours @ $50)	$100,000
Other manufacturing overhead ($900,000 @ 20%)	$180,000
Purchase of reusable equipment	$220,000
Total	$1,300,000

Integrate learning into the bid by relying on the following historical data for the production of 16 DEF rocket launchers.

1.	3,900	2.	3,650
3.	3,100	4.	2,750
5.	2,450	6.	2,475
7.	2,200	8.	2,100
9.	2,150	10.	2,100
11.	1,900	12.	1,850
13.	1,775	14.	1,800
15.	1,750	16.	1,700

2. Prepare a bid for the other model not selected in part 1,using its own learning rate. Determine the amount that it would be under or over the estimate of part 1.

3. Prepare a bid that has no learning. Determine by what amount it would be over from the estimate of part 1.